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| Re:                          | Call for Contributions for Proposed Modification of Specified MAC/PHY standards for WirelessHUMAN™ (TG4); issued 2000-11-17.  |   |
| Abstract                     | This document describes shortly a PHY based on IEEE 802.11a PHY to be used in WirelessHUMAN™ specification. Additionally, link level simulations are given to show the performance in noise and interference limited cases.   |   |
| Purpose                      | The PHY described should be considered as the basic PHY mode of the TG4 standard.   |   |
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# PHY for WirelessHUMAN™

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This paper proposes a physical (PHY) layer for WirelessHUMAN™ standard. Proposal is to use the IEEE 802.11a PHY [1] as such without modifications. We describe only the basic parameters of the PHY and the main purpose of the document is present the performance of the given PHY. For that a set of simulations have been run and a set of results are given in the document.

## 1 The OFDM PHY

The proposal is to use the IEEE 802.11a PHY as such without any modifications, at least as one of the basic PHY modes. The PHY would then be based on OFDM and would use 64-point FFT with 52 active carriers, 20 MHz basic clock rate, convolutional coding with various puncturing patterns and BPSK/QPSK/16QAM/64QAM modulation in sub-carriers. All the relevant parameters are given in Table 1. With these parameters and given modulation, coding schemes and puncturing patterns the PHY will provide for 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s as shown in Table 2.

The two main reasons for proposing the 802.11a PHY as such are that it provides good performance (as shown later) in the given environment and required system features, and cost-effectiveness due to the re-use of an existing PHY standard and COTS chip sets. The current proposal should be considered together with some specific system and MAC level functionalities described in the separate proposal [2]. It is envisioned that when the WirelessHUMAN™ standard contains all the basic interference mitigation techniques on the system level on top of MAC and PHY (DFS, link adaptation control, antenna selection, etc.), a relatively simple PHY that provides for reliable operation in unlicensed bands, is enough and most suitable one. Should the larger delay spreads be tolerated in the system one should incorporate additional PHY modes with higher number of subcarriers allowing longer cyclic prefixes. For mass markets, densely populated areas and high market penetration (i.e. relatively short links and small delay spreads) there should however be a PHY mode that provides for reliable and cost-effective solution like the 802.11a PHY does.

| Parameter                                    | Value                                |
|--|--------------------------------------|
| Basic rate $f_s=1/T$                         | 20 MHz                               |
| Useful symbol part duration $T_U$            | 64*T<br>3.2 $\mu$ s                  |
| Cyclic prefix duration $T_{CP}$              | 16*T<br>0.8 $\mu$ s                  |
| Symbol interval $T_s$                        | 80*T<br>4.0 $\mu$ s ( $T_U+T_{CP}$ ) |
| Number of data sub-carriers $N_{SD}$         | 48                                   |
| Number of pilot sub-carriers $N_{SP}$        | 4                                    |
| Total number of sub-carriers $N_{ST}$        | 52 ( $N_{SD}+N_{SP}$ )               |
| Sub-carrier spacing $\Delta_f$               | 0.3125 MHz ( $1/T_U$ )               |
| Spacing between the two outmost sub-carriers | 16.25 MHz ( $N_{ST}*\Delta_f$ )      |

Table 1. Basic PHY parameters

| Data rate (Mbit/s) | Modulation | Coding rate | Coded bits per subcarrier | Coded bits per OFDM symbol | Data bits per OFDM symbol |
|--------------------|------------|-------------|---------------------------|----------------------------|---------------------------|
| 6                  | BPSK       | —           | 1                         | 48                         | 24                        |

|    |       |     |   |     |     |
|----|-------|-----|---|-----|-----|
| 9  | BPSK  | –   | 1 | 48  | 36  |
| 12 | QPSK  | –   | 2 | 96  | 48  |
| 18 | QPSK  | –   | 2 | 96  | 72  |
| 24 | 16QAM | –   | 4 | 192 | 96  |
| 36 | 16QAM | –   | 4 | 192 | 144 |
| 48 | 64QAM | 2/3 | 6 | 288 | 192 |
| 54 | 64QAM | –   | 6 | 288 | 216 |

Table 2. Rate-dependent parameters

## 2 Simulation results

Simulation of the physical layer was performed with different modes. For every mode Packet Error Ratio (PER) was computed as a function of signal-to-noise ratio either  $E_b/N_0$  or  $C/I$ , where  $E_b$ ,  $N_0$ ,  $C$ , and  $I$  are energy per bit, noise energy, signal power, and interference power, respectively.

In addition the simulations were performed with different channel models. Table 3 presents the channel models and the environments, which are represented by the different rms. delay spreads.

| Channel model | rms delay spread [ns] | Environment description |
|---------------|-----------------------|-------------------------|
| A             | 50                    | Office NLOS             |
| B             | 100                   | Open space/office NLOS  |
| C             | 150                   | Large open space NLOS   |
| D             | 150 (Rice)            | Large open space LOS    |
| E             | 250                   | Large open space NLOS   |

Table 3: Parameters of channel model

Definitions for the symbols in figures:

- ✿ BPSK code rate  $1/2$
- ✿ BPSK code rate  $3/4$
- X QPSK code rate  $1/2$
- ✿ QPSK code rate  $3/4$
- ✿ 16-QAM code rate  $3/4$
- ✿ 16-QAM code rate  $1/2$
- ✿ 64-QAM code rate  $3/4$

The first two curves in Figure 1 show the performance with relatively small delay spreads. One can envision this kind of delay spreads occur also with directional antennas in outdoor environment.

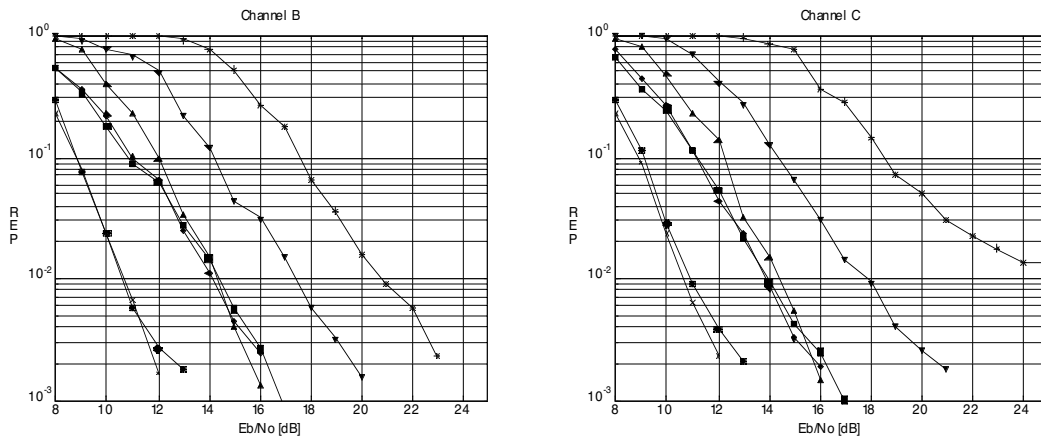


Figure 1: PER vs. Eb/No with channel models B and C.

Figure 2 presents PER as a function of C/I with channel models A, C, and E, respectively.

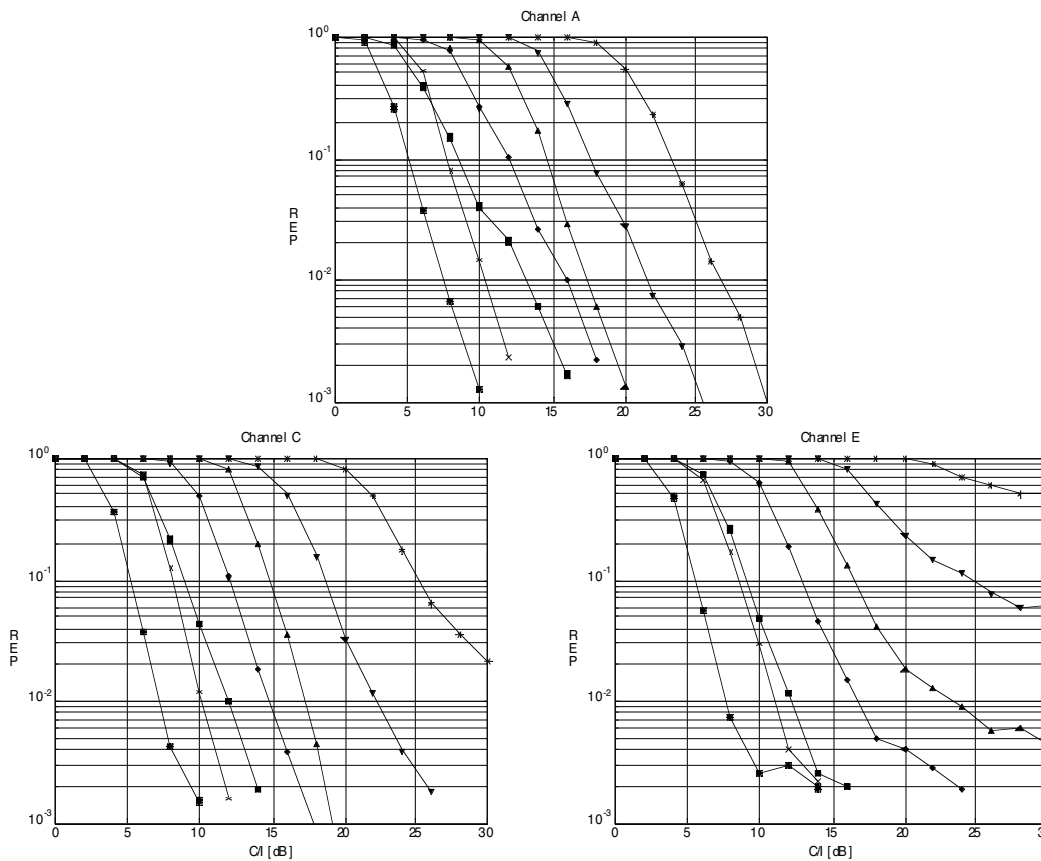


Figure 2: PER vs. C/I with channel models A, C, and E.

From these three curves one can easily see that the large delay spreads destroy entirely the highest bit-rate modes but have very little impact on the most robust modes. If one mandates use of the few lowest modes in control and schedule data transmission there is always a possibility to use any bit-rate suitable for unicast transmission in which directional antenna and transmission can be used.

Last we present some results of the simulations that were run to analyse the effect of the burst length. The two burst lengths used werer 54×8 bits and 9×8 bits. All simulations were run with BPSK code rate \_ and \_. Figure 3 presents PER vs. Eb/No for channel models B and C.

Definitions for the symbols in figures:

- ⊛ BPSK code rate  $\frac{1}{2}$  with burst length  $54 \times 8$  bit
- ⊛ BPSK code rate  $\frac{1}{2}$  with burst length  $9 \times 8$  bit
- X BPSK code rate  $\frac{3}{4}$  with burst length  $54 \times 8$  bit
- ⊛ BPSK code rate  $\frac{3}{4}$  with burst length  $9 \times 8$  bit

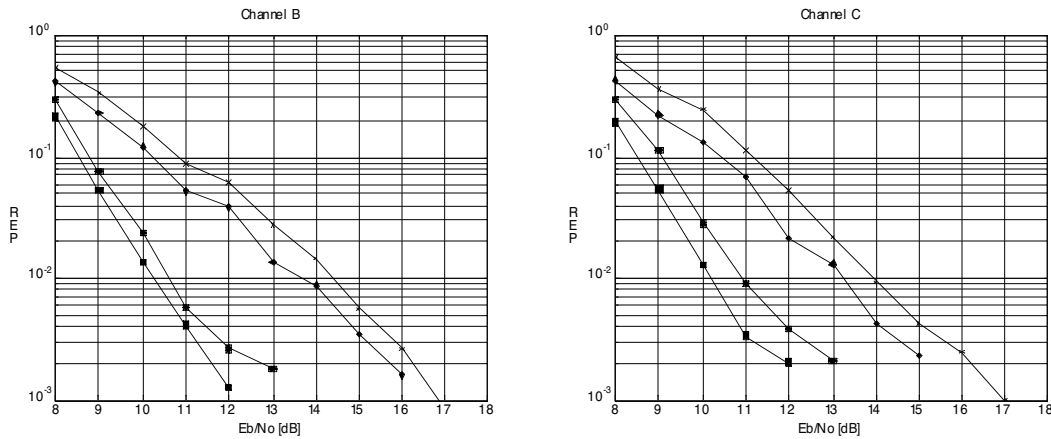


Figure 3: PER vs. Eb/No comparison between burst lengths of  $9 \times 8$  and  $54 \times 8$  bits with BPSK modulation with code rate  $\frac{1}{2}$  and  $\frac{3}{4}$  (channel models B and C).

As we can conclude from Figure 5 the performance is slightly better when burst length  $9 \times 8$  bits are used instead of  $54 \times 8$  bits. The difference between system performances increases when rms. delay spread increases (channel models A, B, C, and E). This is also shown in the Figure 4.

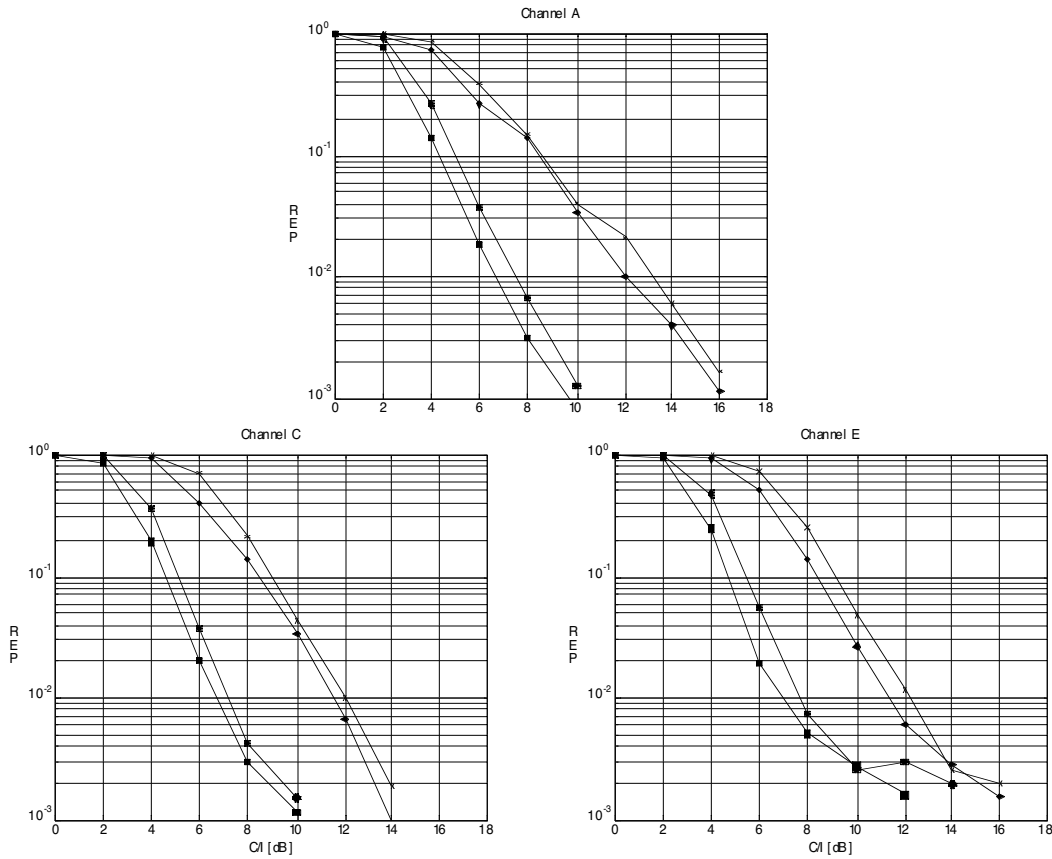


Figure 4: PER vs. C/I comparison between burst lengths of  $9 \times 8$  (■) and  $54 \times 8$  (●) bits with BPSK modulation and with code rates  $\frac{1}{2}$  and  $\frac{1}{3}$  (channel models A, C, and E).

## References

- [1] "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band", IEEE 802.11a-1999
- [2] "A WirelessHUMAN™ System", M.Kasslin, N.van Waes, Contribution to TG4